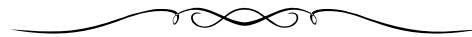




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Mission Design for a Gravity Tractor Demonstration Mission

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Abstract

There are currently three primary techniques studied to deflect a near-Earth object (NEO) from an Earth impact trajectory: (i) the kinetic impactor (KI), (ii) nuclear blast deflection (NBD), and (iii) the gravity tractor (GT). The KI relies on transferring momentum to the NEO through a physical collision with a spacecraft. NBD relies on a nuclear explosion near the asteroid's surface to generate an impulsive push. The GT relies on the gravitational attraction between the target NEO and a hovering spacecraft, changing the object's trajectory slowly but continuously over months to years. These three techniques each have advantages and disadvantages depending on the physical characteristics of the asteroid and the time available before impact.

The Mission Design Division at NASA Ames Research Center has begun a program to develop mission designs for planetary defense. Here we present a mission design for a gravity tractor demonstration mission completed in collaboration with the European NEOShield consortium.

We conducted a trade study to identify suitable target NEOs to demonstrate GT deflection, and found 5 potential known asteroids that have been well studied in the past: 2000 FJ10, 2001 QC34, 2002 DU3, 2001 JV1 and 1998 VO. We selected 2000 FJ10 as the most suitable target to meet the requirements of a GT demonstration mission.

Our GT demonstration spacecraft is based on an ESPA ring main structure and solar electric propulsion (SEP). With a power budget of ≈ 4 kW and an initial wet mass of $\approx 1,150$ kg, the spacecraft would launch in the 3rd quarter of 2024, arriving at 2000 FJ10 in early 2028. The spacecraft mass at asteroid arrival would be $\approx 1,000$ kg.

We estimated the GT's performance based on current knowledge of 2000 FJ10's physical parameters. For an asteroid mass of $\approx 3 \times 10^9$ kg, a diameter $\approx 120 - 210$ m, and an operational hovering altitude of ≈ 250 m from the asteroid's center-of-mass, the GT spacecraft would change the asteroid's semi-major axis by ≈ 2 km over a nominal hovering period of 2 years. To ensure that the deflection is measured, and to permit safe hovering conditions for the GT at all times, a 3-6 month survey and characterization phase would take place after arrival at 2000 FJ10 and prior to tractoring. *In-situ* measurements would include the asteroid's mass, size, shape, spin state, thermal inertia, albedo, chemical composition, and potentially the properties of any satellites or orbiting debris. The notional spacecraft instrumentation suite includes two visible-wavelength cameras, a LiDAR, a MIR camera and a visible-to-near-IR spectrometer. We will present a concept of mission operations including (1) the sequence of operations during the pre-hovering asteroid survey and characterization phase, (2) the guidance, navigation and control strategy implemented for safe and fuel efficient hovering in proximity to the asteroid, and (3) the approach adopted to detect and quantify the deflection achieved, assuming orbit determination accuracy equal to previous asteroid missions.